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EVALUATION OF A MARINE MAMMAL EXCLUDER DEVICE (MMED) FOR A NORDIC 264 MIDWATER ROPE TRAWL

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center

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EVALUATION OF A MARINE MAMMAL EXCLUDER DEVICE (MMED) FOR A NORDIC 264 MIDWATER ROPE TRAWL

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Evaluation of a Marine Mammal Excluder Device (MMED) for a Nordic 264 Midwater Rope Trawl

Dotson, Ronald C. (SWFSC), David A. Griffith (SWFSC), David L. King (AFSC), and Robert L. Emmett (NWFSC)

Introduction

The Southwest Fisheries Science Center's (SWFSC) La Jolla Laboratory of the National Marine Fisheries Service (NMFS) uses a Nordic 264 pelagic rope trawl from Northeastern Trawl Systems (NETS) in Seattle to sample adult coastal pelagic fish species during cruises along the U.S. west coast. The primary objective of these cruises is to measure population dynamics of Pacific sardine (*Sardinops sagax*) in order to set management goals for the coastwide U.S. fishery. The Nordic 264 is also used in salmon (*Oncorhychus* spp.) research by the SWFSC Santa Cruz lab, the Northwest Fisheries Science Center (NWFSC) Newport lab, and the Alaska Fisheries Science Center (AFSC) Auke Bay Laboratories. Issues of bycatch (capture of non-targeted species) are always present, particularly possible encounters with marine mammals (pinnipeds and cetaceans). To reduce any possible marine mammal bycatch during scientific sampling surveys a marine mammal excluder device (MMED) was designed, built and installed in two of the SWFSC Nordic 264 nets and tested during the 2009 field season. The purpose of this project was to develop and test a MMED for use in the Nordic 264 mid-water trawl used by several NMFS agencies in the course of fisheries research.

Methods

In late 2008, Ron Dotson and Dave Griffith, at the instigation of Fisheries Resources Division (FRD) director Russ Vetter, began developing a MMED that could be incorporated into the Nordic 264 trawl. A budget for design, construction and testing was developed and the SWFSC allocated $55K towards the development and implementation of a working MMED in early January 2009. A literature review of existing designs was conducted, and discussions were held with numerous experts from various fields before the building phase was begun. Zollett (2005) provides an excellent review of cetacean bycatch in trawl fisheries and the attendant issues. We decided that a metal grid much like those used as turtle excluder devices (TEDs) (Mitchell, et al. 1995) and MMEDs in other trawl fisheries (Chilvers 2008, Gibson & Isakssen 1998, Northridge 2003, Clement & Assoc. 2008) was the best option. The resultant MMED is an aluminum grate weighing 17 kg (38 lbs), 155cm (61") long and 112cm (44") wide, with 12.7cm (5") spacing on vertical bars (Figs 1 & 2). This MMED is positioned at a 46-47 degree angle pointing upwards towards an escape panel in an intermediary section of netting sewn in just forward of the cod end.

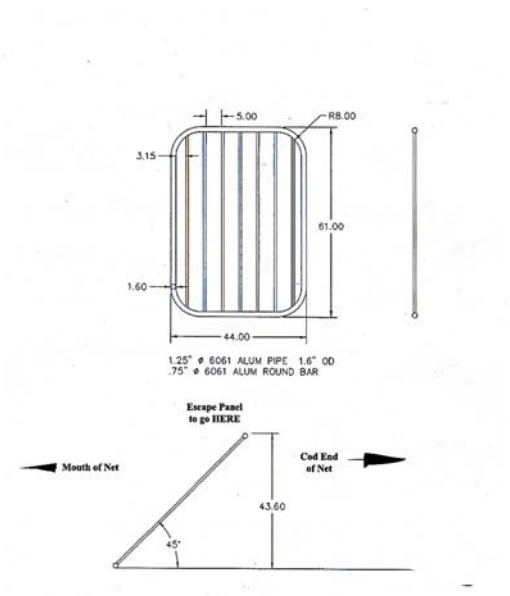

Figure 1. Schematic of the MMED grate design and orientation in the net.

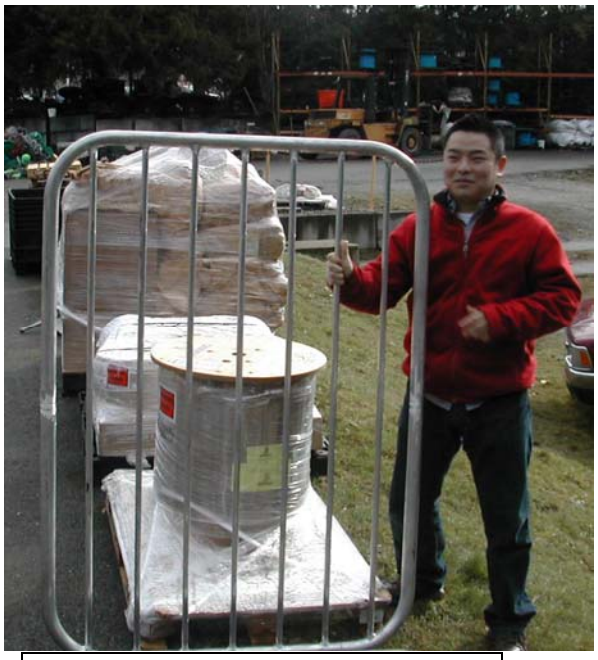

Figure 2. The aluminum MMED grate after construction.

The grate was constructed by NETS of heavy gauge marine grade aluminum made with a 3.2cm (1.25”) diameter outer tube frame and 1.9cm (0.75”) tube vertical bars spaced 12.7cm apart. Spacing requirements were selected based on the skull measurements of the smallest marine mammal likely to be encountered (fur seal, *Callorhinus ursinus*) and the need to allow passage of the target fish species through the grate, as well as other species of interest enumerated during surveys. Placement of the escape panel at the top of the net was predicated on the hypothesis that air breathing mammals would be inclined to attempt to escape upward rather than downward. The net work was done by Dave King and his crew at the AFSC. They were assisted by input from net specialists familiar with TEDs from the Southeast Fisheries Science Center (SEFSC), particularly Charles “Wendy” Taylor, who provided initial consultation and made more suggestions in Seattle during fabrication. The authors felt that “in-house” development and construction was advantageous both in cost effectiveness and because personnel in the AFSC net loft have been maintaining NOAA Nordic 264 nets for several years. The grate was sewn into a 100 mesh deep intermediate section, constructed of four (4) panels of 10.2cm (4") 5mm diameter polyethylene trawl webbing. Each panel consisted of 36 "open meshes" between rib lines. The web was attached to 4 equal length rib lines of 1.9 cm (0.75") Samson Stable Braid rope, and "hung in" 2% of the stretch measurement of the web. The MMED was installed inside the aft end of the intermediate section, 30 meshes forward of the codend. Three (3) 20cm (8") diameter trawl floats were attached to both top rib lines, equally spaced along the MMED frame.

Figure 3. The MMED grate tied into the intermediary panels.

We believe that this intermediary piece of square netting should funnel any marine mammals towards the grate and escape panel (Fig 4), and it also allows for easy addition or removal of the MMED to any existing Nordic-264 trawl.

Figure 4. The MMED grate sewn into the intermediary panels with a large float demonstrating the escape panel above the grate.

Although the intermediary adds 33 feet to the length of the net, it should not result in additional drag requiring more towing power. The bottom edge of the MMED frame was wrapped with line to act as chaffing gear as this portion of the frame would be expected to drag on the deck of the ship. The escape hole at the top panel is cut from the last bar closest to the ribline and leading edge of the frame on each side, along the bar, forward for a total of 24 bars (12 meshes deep) for a hole diameter of 112cm (44”). There are ten “open” meshes that remain in the center of the panel between the two bar cuts. The escape hole is covered with a 3.8 cm (1.5”) knotted, three-strand polyethylene web which is 107 meshes wide by 60 meshes deep and extends beyond the escape hole to lay over the top panel web aft of the MMED (Fig 4).

A MMED was installed in two of the four SWFSC Nordic 264 trawls by the end of March 2009 and the nets were shipped to Port Angeles, Washington and loaded onto the *F/V Frosti*, a commercial trawler contracted by the SWFSC for the spring Pacific sardine survey off the U.S. west coast. Ron Dotson joined the ship in Port Angeles to test the nets during the run southward to San Francisco, California and the beginning of the survey. Two deployments of the net were made during this southward transect. No problems were encountered with deployment or retrieval of the net with the MMED installed. Visual observation indicated that the MMED was oriented correctly at all times (Fig 5).

Figure 5. The Nordic 264 with the MMED installed beginning deployment from the ship.

A Nordic 264 net with the MMED installed was used throughout the sardine survey, April 15-May 9, 2009 along a transect pattern in coastal waters offshore to 300 nautical

miles from San Francisco southward to San Diego. Fifty-seven nighttime trawls were completed with the MMED along with four tows using a Nordic 264 without the MMED. This allowed us to determine if any catch differences existed between trawls with and without the MMED.

The net was towed at speeds of 3.5-4 knots, with the net's head rope fishing just below the surface of the water. The net was spread using NETS 3.0m² XL Lite mid-water doors, which weigh 523 kg (1150 lbs) in air and 136 kg (300 lbs) in water. Tow duration during both surveys was 30 minutes after the net was deployed and the ship was up to full towing speed.

The design and testing budget allocated $40K for a vessel charter for side by side comparisons of the net with and without the MMED installed. Funds were BOPed (Budget Operating Plan) from the SWFSC to a contract for the *F/V Frosti* which was already established by NWFSC to conduct the annual PLUME surveys (Bonneville Power Administration funded studies of the Columbia River plume and salmonids). Five days were allocated on the *F/V Frosti* to conduct this research. The vessel departed Port Angeles, WA on September 15, 2009 to work an area off of La Push, WA. Due to the design and configuration of the *Frosti* and their prior experience with the net in April, the crew was able to rig both trawl nets (one with and another without the MMED) in a "ready to fish" arrangement by spooling the non-MMED equipped trawl onto the net reel and pulling the MMED equipped trawl forward into the trawl alley. With this arrangement, after a net tow was completed a "paired" or comparison net tow could be taken as soon as the vessel moved back to the starting position of the previous set. The second net was deployed and fished over the same track as the previous tow. Approximately ten minutes elapsed from the time of retrieval to the time of the next set. In order to compare catches throughout varying times of day, each twelve-hour work period was staggered over the five days. For day one, hours were 07:00-19:00 and then each twelve-hour work period was advanced by four hours each day. A total of 32 trawls (16 comparisons) were completed over the five-day period.

In order to verify the configuration of the trawl while fishing, it was necessary to visually observe the trawl, specifically in the area of the MMED during operation. Underwater video gear was borrowed from the AFSC (generosity of Craig Rose and Carwyn Hammond) and installed in the net just aft of the MMED (Fig 6). Approximately one hour of video of the MMED during deployment was captured during a day tow and a night tow.

Figure 6. The installation of the video system just aft of the MMED grate in the Nordic 264 trawl.

Every effort was made to avoid marine mammals during all scientific fishing operations. A watch was maintained before and during trawling operations and the net was not set or was immediately hauled back if marine mammals were sighted in the area. For Pacific sardine surveys, trawling operations were the first operations conducted upon arriving on station so that curious marine mammals were not attracted to the immobile ship during station operations. Two 160db acoustic pingers (STM Products) were attached to the footrope of the net to dissuade marine mammals, particularly cetaceans, from entering the net. These criteria were followed during the use of the Nordic 264 trawl in 2009 with the new MMED installed and for all surveys.

Results

No difficulties were encountered launching and retrieving the net with the MMED installed during the surveys. The *F/V Frosti* has a long trawl alley with the net reel set amid ship. The MMED was pulled up into the trawl alley until the cod end of the net was fully on board the vessel and allowed the crew to easily remove the catch. The MMED was located just short of the net reel at these times. The MMED was not wound on the net reel at any time since pressure from the web wound on the MMED might bend or otherwise damage the MMED grate.

The videos confirmed that the configuration of the trawl was not compromised or altered due to the installation of the MMED. All the trawl panels visible in the camera view

were taut and oriented correctly. The escape panel could not be seen during the full towing speed of 3.5-4 knots but it appeared that just before achieving towing speed that the panel does cover the escape opening by water pressure exerted from the outside of the trawl rather than flow from the inside.

Marine Mammals

Seventy-three trawls were made from Washington southward to San Diego, California. No marine mammals were captured in any of the trawl cod ends, despite the fact that both pinnipeds and cetaceans were observed numerous times in the survey regions during daytime transects.

On the April 2009 cruise marine mammals, both cetaceans and pinnipeds were observed during daylight transects along the cruise tracks. Because trawling operations are conducted at night during the Pacific sardine survey, observing marine mammals is difficult unless the animals are very close to the vessel. During one nighttime tow with the MMED, Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) were observed approaching the ship and the ship was stopped and haul back of the net was begun immediately. The dolphins approached the net and four individuals became entangled in the loose meshes hanging down from the stern of the vessel. Two fell out as the net was hauled on board and two were cut from the web and released alive within minutes of entanglement. Because this and all other trawls were conducted at night and the net is well behind the vessel and not visible, we were unable to determine if any marine mammals went into the net and out the escape panel of the MMED during fishing operations. However, no mammals were captured during the September trials with and without the MMED.

Fish Catches

To maintain the continuity of fishery survey databases, it is critical that the MMED not affect fish catches. Among the 61 trawls made during the April 2009 Pacific sardine survey 57 were with the MMED installed net. Three tows were made in an area off of San Diego, CA using the net with the MMED installed and the following night four tows were taken at the same locations without the MMED installed for catch comparisons. Thirty-three of all tows were positive for Pacific sardine. Because there were few comparison tows with and without the MMED on this cruise, and few sardines were captured in those tows, the length frequencies of sardines measured on this survey were compared to those from the April 2008 survey (Fig 7).

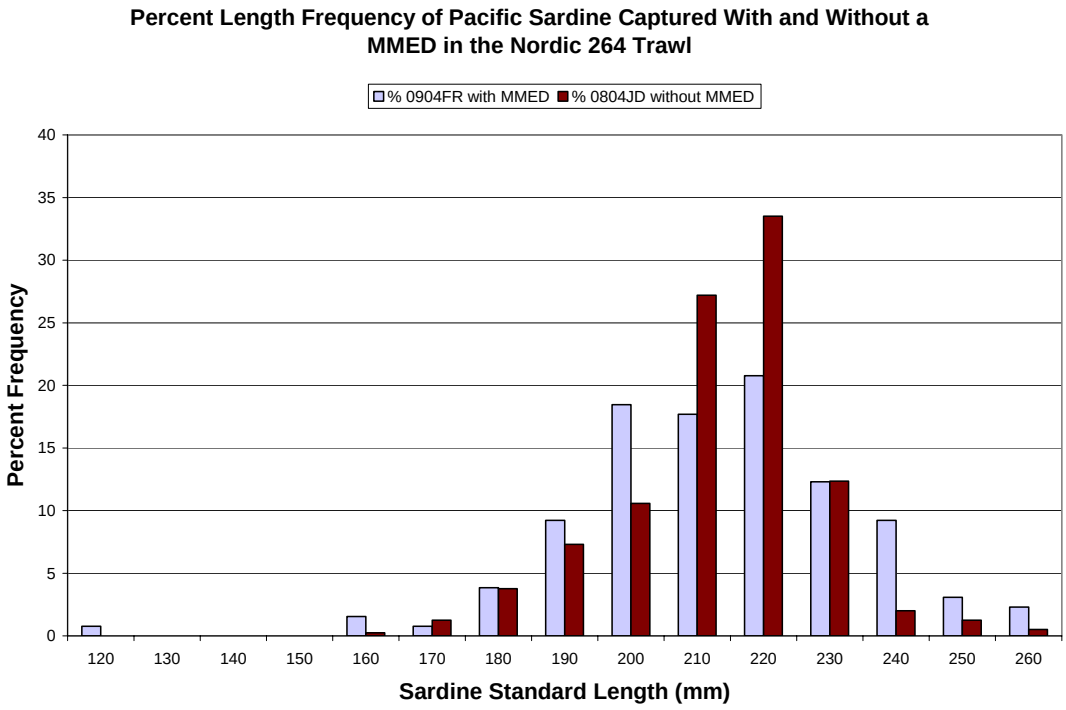

Figure 7. Length frequencies of Pacific sardine (*Sardinops sagax*) caught in April 2009 with the MMED and in April 2008 without an MMED in the Nordic 264

In the catches of the comparison tows off San Diego in April 2009 a number of jack mackerel (*Trachurus symmetricus*) were captured. The length frequencies of jack mackerel caught in these tows are shown in Figure 8.

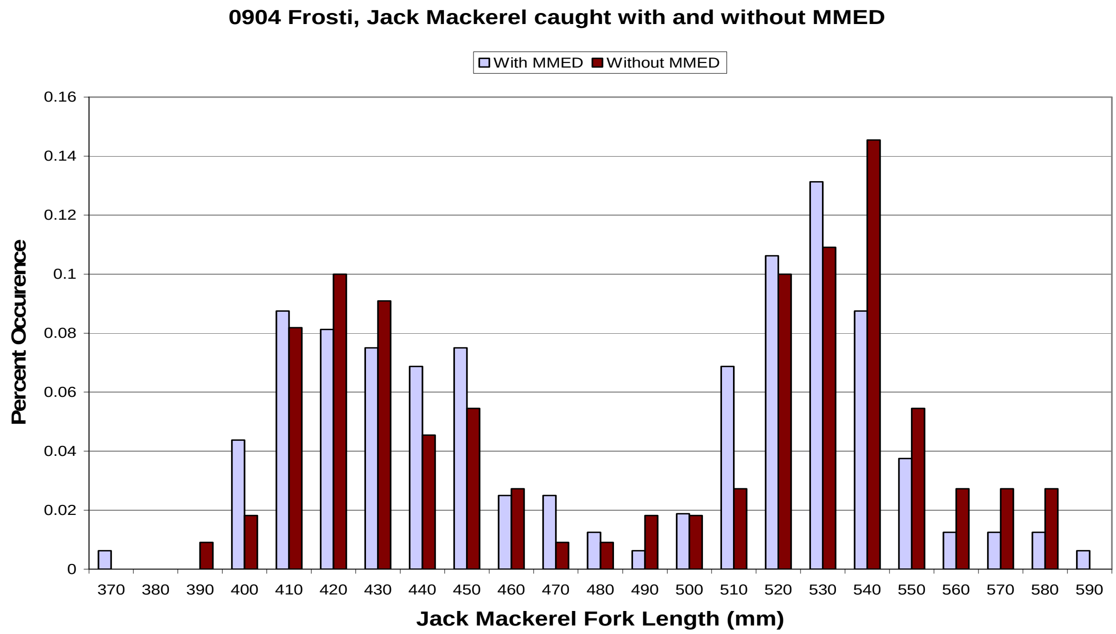

Figure 8. Length frequencies of jack mackerel (*Trachurus symmetricus*) caught in April 2009 in three trawls with the MMED installed and four trawls the following night without the MMED installed in a Nordic 264 trawl net.

More adequate fish catch comparisons are possible for the September 2009 survey when the ship was able to do sixteen pairs of comparison tows with and without the MMED. These catch data are shown in Table 1 below.

Sum of count	Pair MMED																																	
	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		(blank)	Grand Total
Species	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	(blank)	
Abraliopsis sp.				1																														1
Blue shark																			1															1
Chinook									15	13	12	7	1	2		1																		51
Coho						1			6	1	1	1		1		1																3		15
Humboldt squid													21	49	39	5	135	33	4	1	27	13	43	133		12	29	14						558
Jack mackerel																		3	5	3		2	7											20
Loligo opalecens			1																															1
Medusafish																						3												3
Mola mola	2								1				2													1			1					7
No Fish							0	0																										0
Northern anchovy			1	2	8					7358	3280	57	64640	63041	11345	7019													2	4	4642	229		161628
Pacific sardine												1			1															2		4		8
Pacific herring									179	42	94	440																						755
Pacific saury	15	7	13																2		1				3	1	2	1				1		46
Rockfish sp.			1	1																														2
Soupfin shark																					1													1
Steelhead						1																												1
Thresher shark											1																							1
Unidentified rockfish																				2														2
Whitebait smelt		10	20	4	4																													38
(blank)																																		
Grand Total	17	17	36	8	12	2	0	0	201	7414	3388	506	64664	63093	11385	7026	135	36	12	6	29	18	50	133	3	14	31	15	3	6	4642	237		163139

Table 1. Species catches and numbers in paired trawls with (YES) and without (NO) the MMED on the *F/V Frosti* in September of 2009.

Sufficient quantities of two pelagic fish species, northern anchovy (*Engraulis mordax*), and Pacific herring (*Clupea pallasii)* were captured in the comparison tows to allow length frequency comparisons. These data are shown in Figures 9-10.

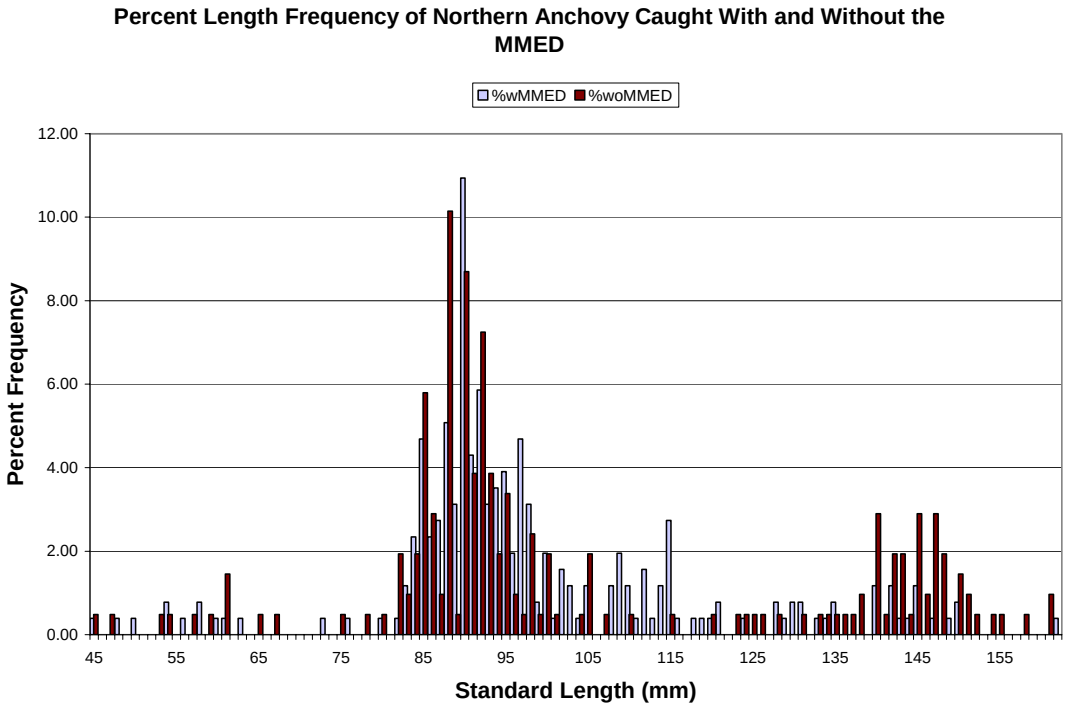

Figure 9. Length frequencies of Northern anchovy (*Engraulis mordax*) caught during September 2009 in paired trawls with and without an MMED in a Nordic 264 trawl net.

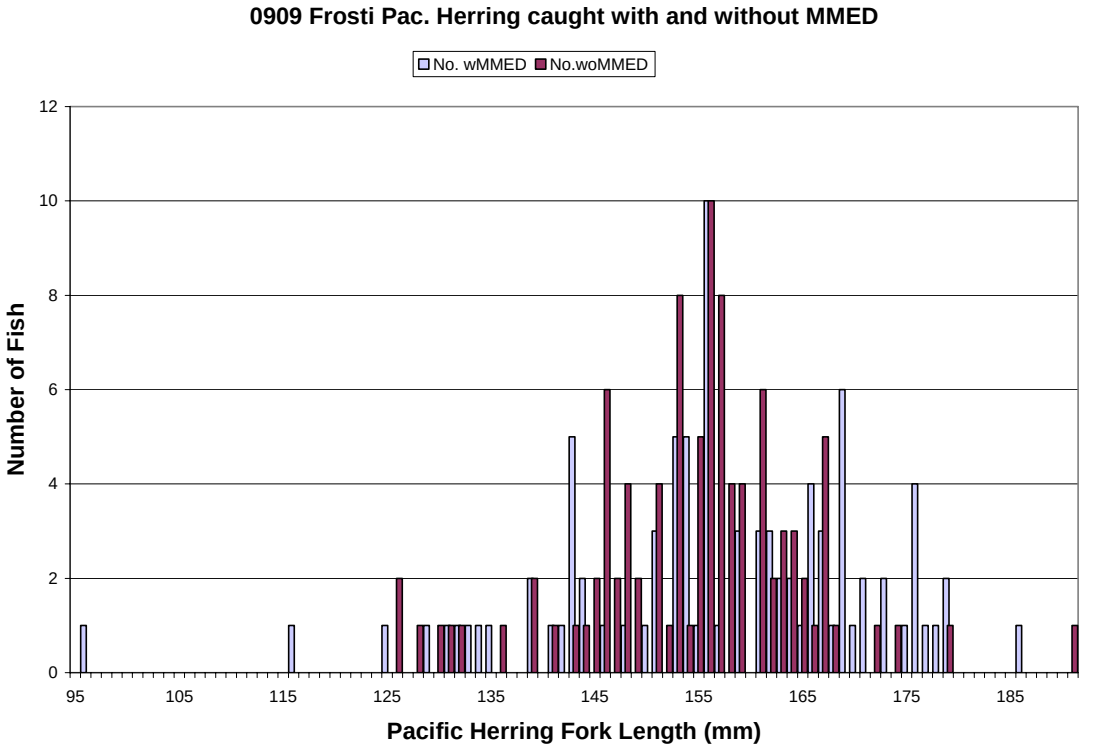

Figure 10. Length frequencies of Pacific herring (*Clupea pallasii*) caught during September 2009 in paired trawls with and without an MMED in a Nordic 264 trawl net.

A signed rank test on the catch data from the paired tows was done to determine if there was any difference in the total catch for each paired trawl (with and without the MMED). This test does not assume any normal distributions and was used due to the patchy distributions of nekton. The data was not transformed before analysis. In this test, the null hypothesis is median equals 0.0, with the alternative not equal. The average rank of values below the hypothesized median was 8.875 and above the hypothesized median the average rank was 9.750. The large sample test statistic equals 1.50006 (continuity correction applied) with a P value of 0.1336. We do not reject the null hypothesis for alpha equals 0.05. This statistical analysis indicates that there was no statistical difference between the total nekton catch between trawls with and without the MMED.

Squid

In addition to fish catches, large numbers of Humboldt squid (*Docidicus gigas*) were collected during the MMED comparison study. Mantle lengths are shown in Figure 11. We captured similar numbers of squid with (260) and without (298) the MMED. Although this is a relatively small sample size, the catch difference was only 13% between the two net configurations. Nevertheless, at least some of this difference can be attributable to large squid going out the escape panel of the MMED. During one tow with video gear attached we observed the squid hitting the MMED and escaping out the upper panel.

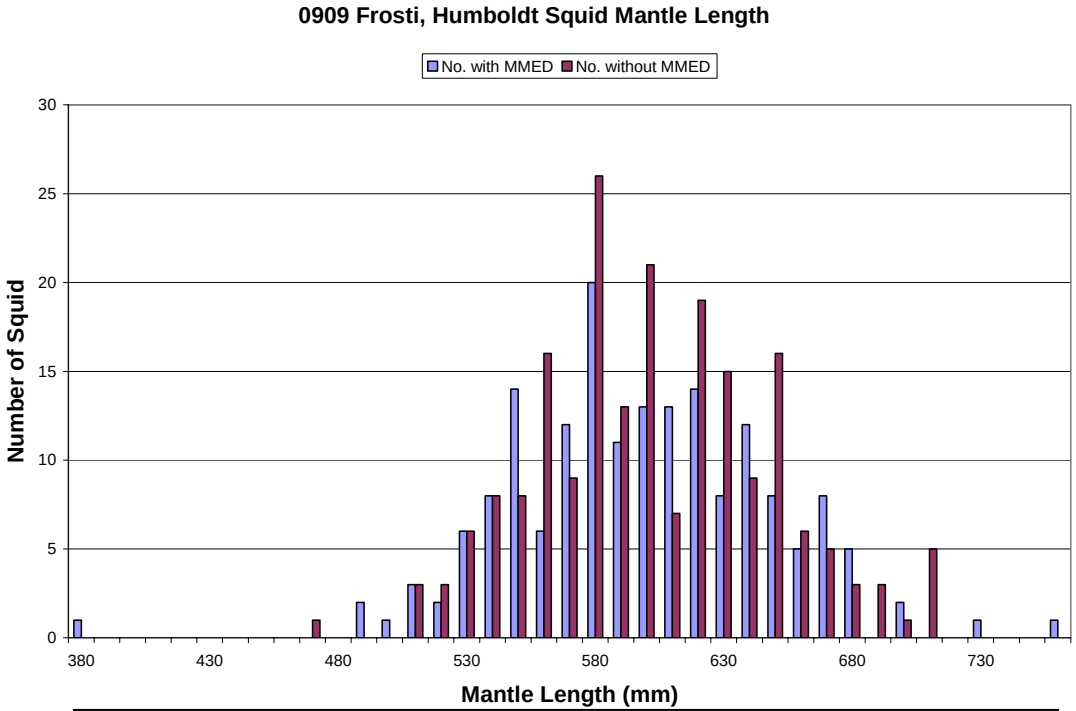

Figure 11. Length frequencies of Humboldt squid (*Docidicus gigas*) caught during September 2009 in paired trawls with and without an MMED in a Nordic 264 trawl net.

Discussion

There is an historical database using the Nordic 264 trawl in both the Pacific sardine and salmonid research projects. Changes to the trawl configuration immediately raise questions about the effects these changes may have on the nekton catches and may compromise the integrity of the data series. Primary concerns expressed to date have been: 1) Will the MMED effectively prevent marine mammals from being caught?, 2) will fish or nekton target species escape out the escape panel or be scared out of the trawl by inclusion of a grate in the throat of the net?, 3) could there be size selectivity on the target species, where larger or smaller fish are omitted from the catch?, 4) would catch quantities be affected?, and 5) what would be the effects on catches of other species, some of which are studied to a greater or lesser degree as part of the research projects?

If the MMED affects the catches of the target species it would preclude comparisons of data from MMED trawl tows to historical non-MMED Nordic 264 trawl data. The trawls done this year indicate that installation of the MMED in the Nordic 264 trawl does not bias or alter nekton catches. The length frequency of Pacific sardine caught during the April 2009 sardine spawning survey ranged from 120-260mm, which qualitatively compares favorably with the length frequency range of 160-260 mm in the April 2008 survey (Fig 7). Likewise, the length frequencies of jack mackerel caught in comparison tows ranged from 380-600 mm with the MMED and 400-590 mm without the MMED, again within similar size class distributions (Fig 8).

Northern anchovy and Pacific herring are two other pelagic fish species which the NMFS is responsible for monitoring. The length frequency comparisons of those species caught during sixteen paired comparison tows in September 2009 also show similar ranges and size class distributions, with sizes ranging from 45-163mm for northern anchovy and 96-190mm for Pacific herring (Figs 9, 10). Due to the patchy nature and tight schooling behavior of the coastal pelagic species encountered in the paired trawl studies, it is difficult to equate total catches between tows. However, neither net configuration seemed to consistently produce larger or smaller catches (Table 1). The lengths of target species sampled during both the April and September cruises ranged from a low of 45mm to a high of 600mm, with no apparent difference in net size selectivity with or without the MMED. The signed rank test done on total catches to determine a difference with and without the MMED showed no difference between the two nets.

The population of Humboldt squid has recently increased off the U.S. west coast and now ranges from southern California to Alaska during the summer and fall. Large numbers of squid were captured off Washington during the September 2009 survey. Mantle lengths of squid caught with and without the MMED were comparable, ranging from 380-760mm with the MMED and 470-710mm without the MMED, and are considerably larger than the pelagic fish species sampled. The total numbers of squid caught with the MMED installed were slightly less than those without it. As noted earlier, the video footage showed Humboldt squid which struck the grate crosswise immediately slid up the grate and out the escape panel. Those that hit the grate head or “tail” first went through

the grate and into the catch, although some were observed to grab the grate with their arms and tentacles, pull themselves back through and out the escape panel.

During the September 2009 survey salmon were the target species. However, relatively few salmon were caught: 28 Chinook salmon (*Oncorhynchus tshawytscha*) without the MMED, and 23 with the MMED, while for coho salmon (*O. kisutch*) only 7 were caught without the MMED and 8 with the MMED. Due to these very small numbers further comparisons will be necessary to determine if the MMED affects salmon catches, but the initial catches seem to indicate little effect.

The catches from the April 2009 survey and the MMED tows during the September 2009 survey included no sharks. Three sharks were caught in three separate non-MMED trawls in September, one blue shark (*Prionace glauca*), one soupfin shark (*Galeorhinus zyopterus*) and one common thresher shark (*Alopias vulpinus*). Historically, we have caught at least one large blue shark, shortfin mako shark (*Isurus oxyrinchus*), salmon shark (*Lamna ditropis*) or common thresher shark during our April surveys. Although it was not possible to observe the escape panel when fishing the net, we believe that large sharks likely entered the net with the MMED installed and were shunted out the escape panel, similar to what was observed for the squid. Likewise, five large and one smaller ocean sunfish, *(Mola mola),* were caught without the MMED installed. Large sunfish appeared to have been expelled from the catches with the MMED since only one smaller sunfish was captured. In April 2009, two large ocean sunfish were entangled by their dorsal and ventral fins in the web just forward of the MMED grate and were disentangled and released alive when the net was retrieved, while several smaller sunfish went through the grate and were found in the cod end of the net with the remainder of the catch.

We feel that this ancillary catch information is promising from a couple of aspects. Although some genetic studies are done by the SWFSC on sharks that are part of the bycatch during our Pacific sardine surveys, these fish are frequently in poor condition when removed from the net and their survival after release is unknown. Other than a total length measurement and estimated weight before release, ocean sunfish are not studied by the SWFSC or NWFSC. Hence exclusion by the MMED of these animals is probably beneficial for their survival and has minimal impact on the scientific information gathered. In addition, and more importantly, the apparent exclusion of these larger fish from the MMED indicates that the grate and escape panel are working as designed and any marine mammal encountering the grate would also be expelled from the net.

The one incident where marine mammals were observed to encounter the trawl net was when a school of Pacific white-sided dolphins approached the ship and the net was hauled back and the vessel stopped. Some of the dolphins swam into the slack web hanging from the vessel and became entangled, with two animals having to be cut from the webbing and released within a few minutes after entanglement. Under these conditions there was no water flowing through the net and all of the webbing was collapsed, hence the dolphins did not go into the net nor did they encounter the MMED. In the future when marine mammals are observed approaching the vessel during fishing

operations we suggest that the net be hauled back while the vessel maintains speed so that any animals that do get into the net have the opportunity to either swim out of the large mesh portion of the net, or are funneled down to the MMED where the force of the water and their own swimming action will allow them to escape out the escape panel.

Acknowledgements

This project was initiated with a short timeline and no initial budget. Our success is due to a high degree of cooperation and valuable input from numerous personnel spread over different agencies. This cooperation allowed us to quickly define the best probable means by which to resolve a problem with marine mammal bycatch, define the parameters for designing the MMED, meld the design with several diverse research projects, construct and install the MMED quickly and inexpensively, and successfully test the system. The persons instrumental in assisting this project include, but are not limited to: Norm Bartoo Deputy Science and Research Director (SWFSC), Roger Hewitt, Assistant Center Director for Ships and Infrastructure (SWFSC), Russ Vetter, Fisheries Resource Division leader (SWFSC), Lisa Ballance and her staff in the Protected Resources Division (SWFSC), Jim Smart, equipment specialist in the net loft at the Alaska Fisheries Science Center (AFSC) as well as the rest of the net loft crew, Russ Nelson, head of the RACE Division at the AFSC, Doug DeMaster, Director AFSC, Joe Orsi, researcher at AFSC, Craig Rose and Carwyn Hammond, video specialists (AFSC), Charles (Wendy) Taylor, equipment specialist at the SEFSC, the *F/V Frosti* owners and crew who always go above and beyond, Koji Tamura, net design specialist at NETS in Seattle, and Richard Wells, Clement and Associates, New Zealand.

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